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U.S. Army Research, Development and Engineering Command

# Fluorinated Carbon Composite Cathode for a High Energy Lithium Battery



***TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.***

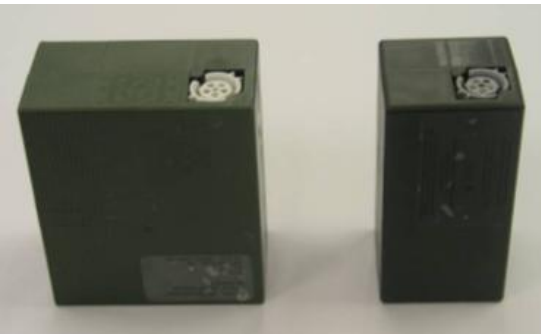
Inventors: Drs. Shengshui Zhang, Donald Foster, Jeff Wolfenstein, and Jeffrey Read

## Technology Overview

Lithium/carbon monofluoride ( $\text{Li}/\text{CF}_x$ ) primary batteries have double energy density over state-of-the-art  $\text{Li}/\text{MnO}_2$  and  $\text{Li}/\text{SO}_2$  primary batteries (theoretically 2203 Wh/kg vs. 847 and 1150 Wh/kg, respectively). However, these batteries suffer initial voltage delay and high polarization, especially in high power or low temperature operating conditions.

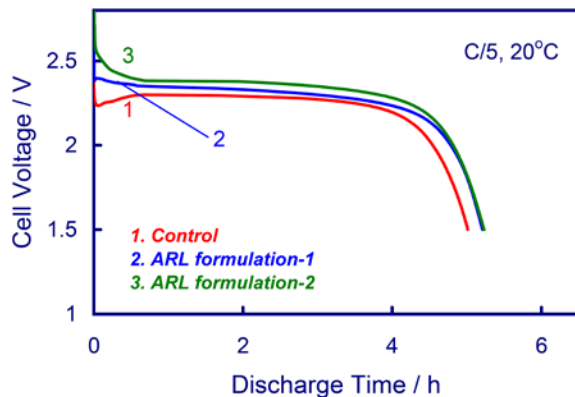
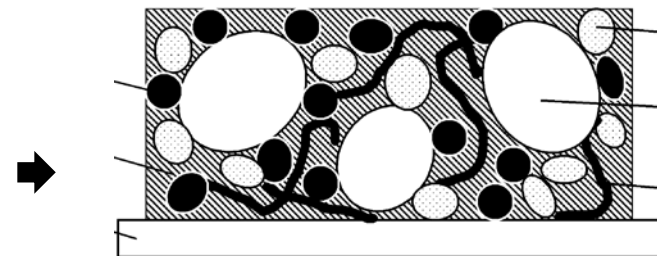
This invention relates to a high energy density  $\text{Li}/\text{CF}_x$  primary battery technology with substantial reduction in initial voltage delay and battery discharge polarization. These significant improvements are achieved by simply adding small amounts of metal oxide additive and carbon fiber into the existing cathode formulation. All added materials are inexpensive and commercially available, and the technology does not require additional production process. The ARL team has achieved proof-of-concept and reduced the invention to practice, with reproducible results.

## Technology Overview



← Use of Li/CF<sub>x</sub> batteries could reduce the volume and weight of a BA-5590 lithium battery by 50 % while still remaining the same energy capacity.

This innovation adds 1~5% by weight non-electroactive metal oxide to existing CF<sub>x</sub> cathode formulation to alleviate or even remove initial voltage delay, and further adds 1~2% by weight highly conductive carbon fiber as a part of the conductive agent to increase discharge voltage of the batteries.



← This innovation not only reduces or even eliminates the initial voltage delay, but also increase discharge voltage without any loss in capacity.

## Technology Advantages

This invention increases discharge performance of  $\text{Li}/\text{CF}_x$  primary batteries by:

- Reducing or even eliminating the initial voltage delay. In many cases, the initial voltage delay can last up to 20 minutes, which results in a difficult startup of equipment. Pre-discharging has been used to pass the initial voltage delay, however, this process requires additional production lines and sacrifices about 10% energy capacity.
- Providing higher discharge voltage without loss in the capacity.

This invention also provides the following additional advantages:

- Uses commonly-available materials.
- Cost is comparable with existing  $\text{Li}/\text{CF}_x$  production lines.
- Easy scale-up and drop-in technology applicable to existing production lines.

## Technology Differentiation

Compared to the competition, the novel fluorinated carbon composite cathode will:

- Reduce or even eliminate the initial voltage delay for easy startup of the battery-powered equipment.
- Increase at least 3% battery power by increasing battery discharge voltage, depending operation conditions, for example, 3.8% at a 5 hour discharge rate (C/5) and at room temperature.
- Generate less heat during discharge due to a reduction in the battery polarization.

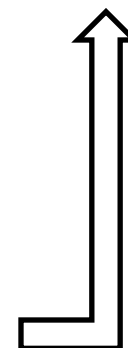
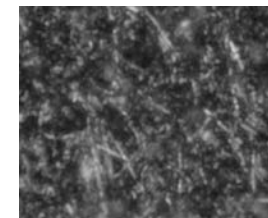
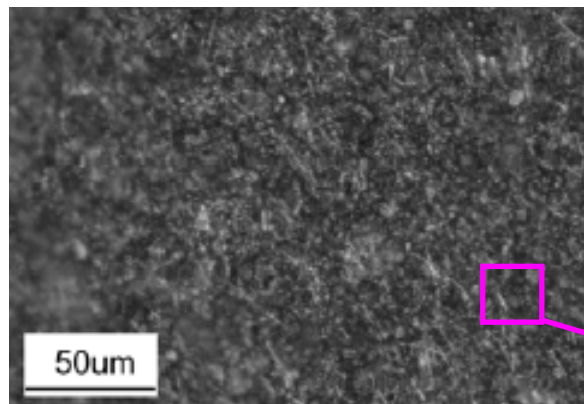
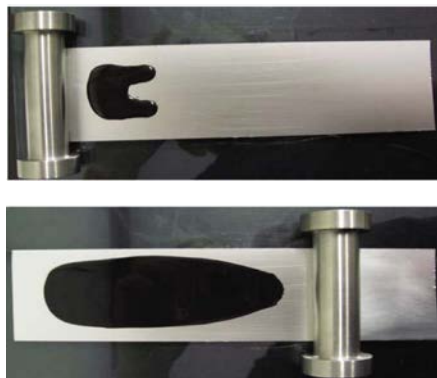
### EXAMPLES:

1. New  $\text{Li/CF}_x$  batteries have initial voltage delay, these batteries could not start equipment if the operation is in high power or low temperature condition. The invention reduces or even eliminates the initial voltage delay of  $\text{Li/CF}_x$  batteries, allowing these batteries to be used in a wide range of applications from military to commercial electronic systems.
2. A soldier currently requires carrying about 50 lbs of batteries. The invention reduces the overall weight and volume of the battery by 50%, allowing the soldier to carry other essential equipment.

## Technology Proof of Concept

To date, the fluorinated carbon composite cathode has been reduced to practice by:

- Demonstrating the optimized formulation of  $CF_x$  composite cathodes
- Building and testing Li/ $CF_x$  coin cells by using the cathode formulation of the present invention
- Achieved a TRL 5



*$CF_x$  composite cathode with 1 % by weight carbon fiber added as conductive agent*



## Military Applications

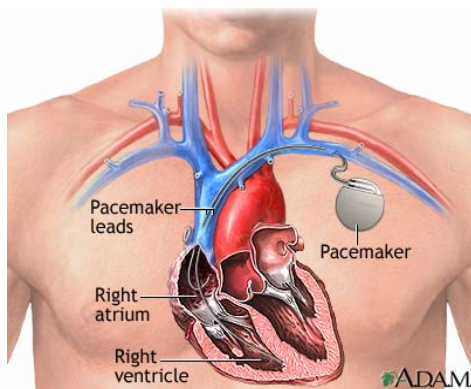
- Soldier portable power for long term missions, e.g., BA-5590 lithium battery
- Military electronics, for example, silent watch, night vision, radio, GPS etc





## Commercial Applications

Due to high energy density, excellent thermal stability and extremely low self-discharge rate of Li/CF<sub>x</sub> batteries, immediate commercial markets are in a wide range of long-term, low-to-medium current applications from memory backup, implant medical devices, search & rescue communications, oil drilling sensors to aerospace electronics.



Dynamic Pacemaker



Meter Transmitter Unit



Smart Utility Meter

## Technology Agreements

A Patent license and CRADA are sought.

The current technology would benefit from a collaboration between the inventor team and the commercialization partner in order to speed the development to the market. This would most readily be done through a patent license and a CRADA agreement. The inventor team is available to work with commercialization partner.

TRL 5 – Fully functioning prototype cell fabricated using ARL process

A patent application has been filed